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Thermovision

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Arctic field work in building technology
Thermo vision

Petra Vladykova, pev@byg.dtu.dk

Field work: 3 weeks in August 2007 (site visit)

Report: 9rd January 2008

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I would like to thank all participants for cooperation and help with measuring. Special thanks to Viktor Zwiener, Dekprojekt, for information and help with analyzing results.

1 Background and Greenland´s housing situation

Greenlandic housing situation is in great need of renovation, especially in the terms of thermal insulation and refurbishment. Currently around 80 % of all energy consumption in Greenland is used for heating the buildings. This situation has arisen due new buildings which have been built and given priority over the maintenances of old houses. Also there is a big need for complete and proper registration of dwellings all over Greenland. The standard and typical plans and drawings of residential dwellings have been used and there is maybe one of sources of typical errors in buildings as well as regular maintenance and proper renovations of those houses. [1]

Also the lack of good building materials available on European markets but highly over-priced in Greenland (added transport costs) has become one of the issues in previous Greenland´s buildings.

Figure 1: Greenland

This report could be a starting example of registration of building and their state in current condition of thermal insulation, condition of windows and building's envelope situation.

2 Thermovision

2.1 What is thermo vision?

Thermo graphy is contactless method for measuring intensity of infra-red emission on the surface of objects. Thermo gram is an image which shows where the heat emission is coming through the building/building components out. Red indicates the critical parts where the heat escapes and blue areas are where the less heat is lost. This rule is valid only for the measuring of the buildings from exterior with typical heat flux from interior to the exterior.

Thermo measurements can be used to determine the current condition of building and its constructions which can lead to determine the situation of walls or thermal insulation (thermal bridges, connection points, exhaust ventilation, etc.).

Thermo graphy measurements can illustrated how the U-value of building element was improved by for instance change of windows (or adding insulation), where the measurement is taken before installing the new windows and after.

2.2 The advantages of infrared thermo graphy

- the measuring can be taken in very fast time and without any disturbance to building process (real time measurements)
- it is possible to determine the corrections and their priorities
- it is possible to eliminate not planned failure and shutting down of device
- it is possible to decrease the need and range of precautionary repairmen and controls
- it is possible to check the device while it is in use and running
- it is possible to check the new equipment
- non-destructive test method

2.3 Where else thermo vision can be used?

- Building industry (detecting of the places with lower insulation, with increased dampness and with increased infiltration; heating systems, flat roof)
- Generation, power distribution and power consumption (generators and transformers; equipment of control rooms; electrical circuit)
- Mechanical Engineering (production technology, engines, bearings, gear unit)
- Petro-chemistry industry (refinery, exchanger, kiln)
- Foundry industry (insulation, technologic process)
- Electronic industry (plate of printed circuit, binders)
- Human environment (landfills, reservoirs, rivers)
- Research and development (new systems)
- Automobile industry (pneumatics, engines, brake systems)
- Aerospace industry and applications (wings, engines, composite materials, constructions)
- Medicine industry and veterinary applications (oncology, stomatology, physic straining, inflammatory process)
- Detecting fires, etc.

3 Thermovision measurements

Purpose of the performed thermo measurement was to determine the current situation of insulation condition and level in Greenlandic resident and commune buildings.

For measuring was used the thermo camera ARTRAY ARTCNV-NECS1 and for data evaluation was used software Viewer Program (TH78-719).

Figure 2: Thermo camera

The thermo camera is not measuring directly the surface temperature, but the temperature is calculated based on the measuring of infrared emission and boundary conditions. Important boundary condition is emissivity of surface; this depends on the material properties and the surface finishing of material ($0 \leq \varepsilon \leq 1$). Note: material with threshold limit of the emissivity does not exist in real world. The next boundary conditions are: the distance between camera and object, relative humidity and air temperature. The transmissivity of atmosphere can be calculated from these boundary conditions.

The results of thermo graphy measurement can determine the surface temperatures and check the conditions of insulation. Furthermore with the more complex software and experiences could be determined the heat fluxes, mould risks and surface condensation on interior side. More complex data such as condensate water vapour in construction, heat loss of construction or U-value (coefficient of heat transmittance) could be determined and calculated. [2]

3.1 Theoretical conditions and acceptable results

- Minimum temperature difference 8 °C between interior and exterior
- Weather conditions: no snow, no fog, no rain (water is totally radio-opaque for infrared measuring)
- Time: during the heating season (between September and May – for Europe conditions; the whole year – for Greenland), in morning hours (fixed heat flux and no sun shining on the object)

3.2 Real-time conditions

- Temperature difference and time

The measurements were taken in summer time in August 2007 and as the thermo measurement requires at least the temperature difference between indoor and outdoor temperature 10 °C (better 15 °C), the conditions had to be regulated a little bit. In order to get acceptable results, the measured houses were inside heated to approximately 30 °C.

Temperature difference	Inside [°C]	Outside [°C]	Δ T [°C]
Low Energy house, Sisimiut	27.5	9	18.5
Single family house, Sisimiut	30.3	7.4	22.9
Single family house, Sarfannguaq	29.1	9.5	19.6
Elementary school, Itilleq	29.0	10.6	18.4

Table 1: Temperature difference indoor/outdoor of buildings

The measurements were taken once in morning/afternoon hours to establish the best position for thermo camera and also for the documentation images of normal camera. The second measurement was taken after midnight to let the building cool down and to avoid the sun reflection on building surface.

- Weather conditions

The weather was mostly cloudy during the night measurement with no fog and rain. Therefore from this part the boundary conditions are on satisfied level.

- Technical investigation of conditions

Registration of conditions (temperature outside, inside the house)
Initial registration of the quality of the houses (size, layout, used materials, dimensions, configurations of constructions including windows)

3.3 Parameters

For analyzing images it is necessary to know 3 basic parameters:

1) Emissivity of building´s materials
2) Reflected "temperature" (energy),

It is the temperature of objects behind the measured construction (for instance if the camera is directed on the object and the person taking measurements can reflect "thermally" in that material, then the temperature of human body needs to be known).

3) Transmissivity of atmosphere

It can be calculated from temperature, relative humidity and distance from object and camera, but mostly those parameters (transmissivity of athmosphere, temperature of air and humidity, reflected emissivity, distance) could be calculated directly from camera and more complex software itself.

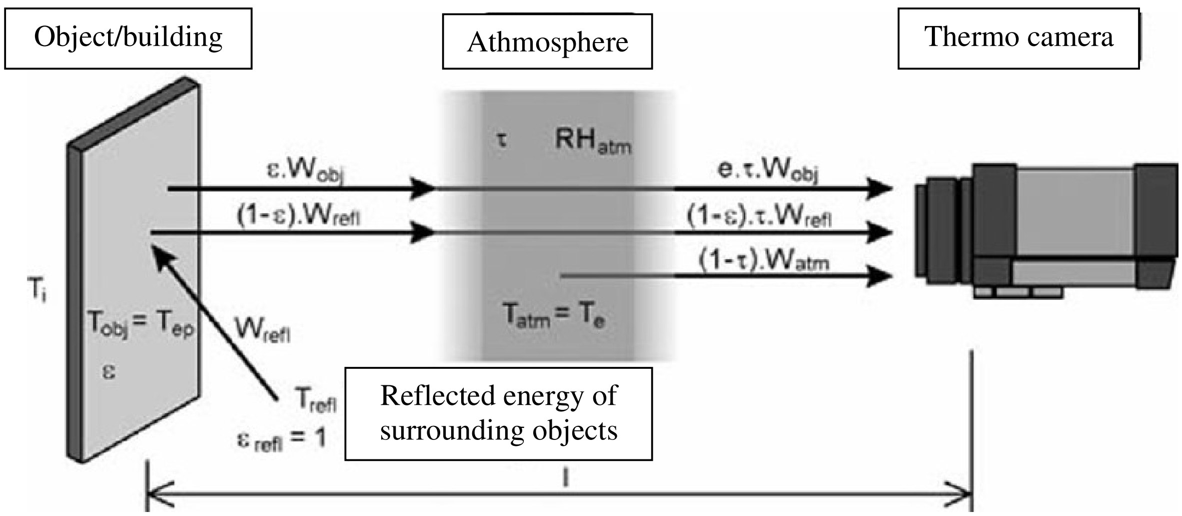

Figure 3: Scheme of thermo graphic measurements and boundary conditions [3]

Emissivity ε is a modifying factor used in single colour thermometry to achieve a correct temperature reading. Emissivity or radiating efficiency of most materials is a function of surface condition, temperature and wavelength of measurement.

Emissivity is the capacity of each body to radiate from surface and it is called the emissivity of surface. Emissivity is the rate of energy emitted from real surface and absolute black body.

$$\varepsilon = \frac{H_m(T)}{H_C(T)}$$

where: $H_m(T)$ is energy emitted from measured object with temperature T
$H_C(T)$ is energy emitted from black body with temperature T

Most organic, painted, or oxidized surfaces have emissivity values close to 0.95. Glass with temperature range 20 - 100°C has emissivity 0.94 – 0.91 (reference values). [4]

Emissivity ε	[-]
Wood	0.95
Concrete	0.94

Table 2: Emissivity of wall materials (reference values)

Furthermore the emissivity can be exactly determined and measured (if the exact value cannot be found in literature) with device called pyrometer. Other ways how to measure exact emissivity value of materials are [5]:

- measuring of sample in specialized laboratory
- increasing emissivity of material´s surface with covering its surface with black band or spray application with special thermal resistant colour with ε ≈ 1
- measuring temperature characteristics of material´s sample
- field test of measured temperature with stylus instrument
- comparison of radiation measuring with value obtained from ratio pyrometer

Transmissivity of atmosphere is coefficient which depends on the transmissivity of atmosphere (depends on its "clearness"), and mostly is between 0.7 and 0.9. The coeficient is influenced by humidity (maximum is in the winter, minimum is in the summer => for the European conditions; in Greenland the humidity is on minimum in the winter and on maximum in the summer). Coefficient are reference values. [6]

U-values	Wall material insulation
Low Energy house, Sisimiut	Insulation 300 mm Calculated U-value 0.15 [W/m^{2}K]*
Single family house, Sisimiut**	External wall: 100 mm Rockwool (existing) + 75 mm new glass wool insulation Winter garden: 50 mm Basement: 63 mm glass wool insulation
Single family house, Sarfannguaq	150 mm Rockwool
Elementary school, Itilleq	130 mm insulation total

Table 3: Insulation of building´s walls

*U-value demanded 0.20 [W/m^{2}K] from coming building code of Greenland (GBR)
**Vejrstation type 4, built 1947

4 Background of buildings

Low Energy House (LEH), Sisimiut

Low Energy House has been built in 2005 with new construction technology and with a larger focus on energy consumption and efficiency. Its area is 200 m^2 and it is a double house build by Technical University of Denmark and Sanaartornermik Ilinniarfik (The Building and Construction School of Sisimiut) with funding from the Villum Kann Rasmussen foundation. U-value of walls can be found in Table 3.

The Low Energy House is a very good example of a low-energy house and will be taken as comparison example for other buildings.

Figure 4: Low Energy House (LEH), Sisimiut

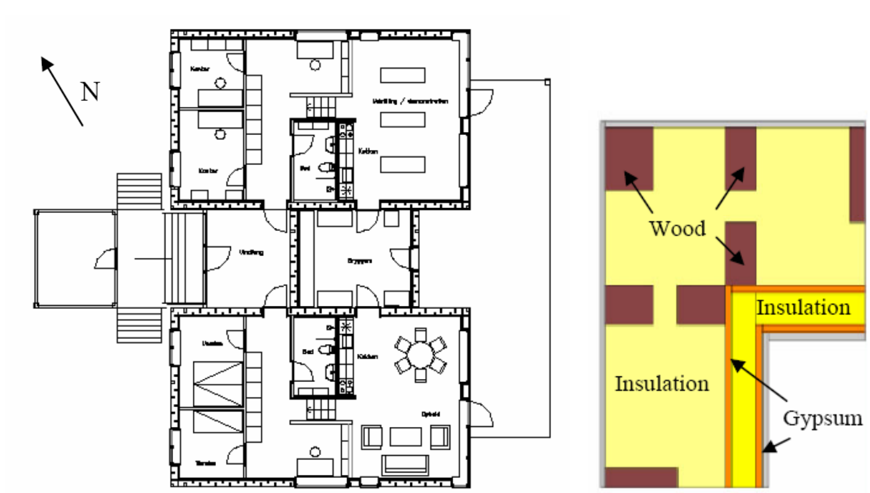

Figure 5: LEH, floor plan and cross section of wall

Single family house (SFH), Sisimiut

Family house in Sisimiut is a standardized typical house from 1947 which has been renovated in 1989 with area 150 m^2. Its heating costs are 12 000 -14 000 DKK per year and they usually heat the house for 20 °C.

The owner of the house would like to decrease the heating consumption by insulating the house and there are complaints from too cold part of the house where the winter garden is (wind coming from the sea).

Figure 6: SFH, Sisimiut

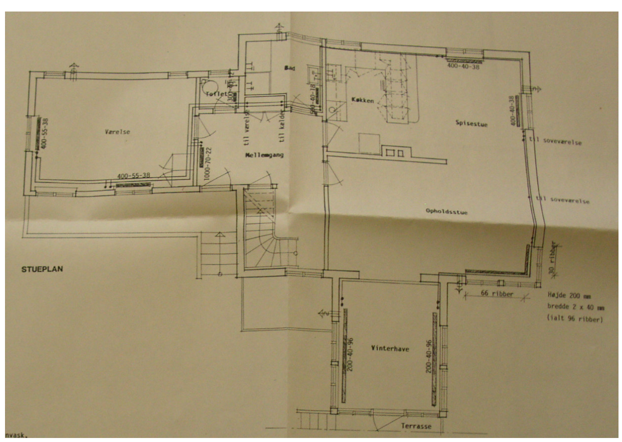

Figure 7: SFH, Sisimiut, ground floor plan

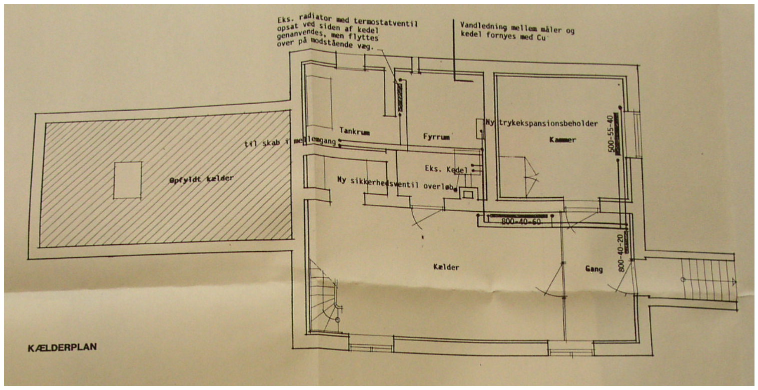

Figure 8: SFH, Sisimiut, basement floor plan

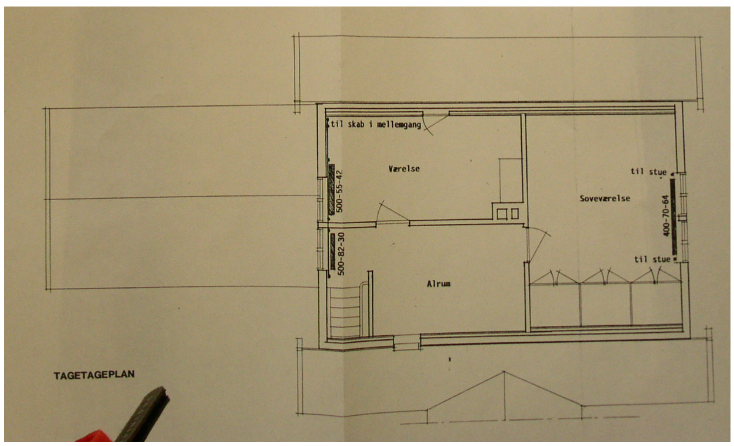

Figure 9: SFH, Sisimiut, first floor plan

Single family house (SFH), Sarfannguaq

The next single family building is also a typical family house built in 1982, floor area 85 m^2 and its current insulation is 150 mm. The owner of the house has recently have changed the windows and door, and is thinking also about the extra insulation for walls. The windows are energy class A 1,1*.

Figure 10: SFH, Sarfannguaq, without new windows

Figure 11: New and old doors

Figure 12: New and old windows

Elementary school (ES), Itilleq

The elementary school in Itilleq has been built in 1952 and renovated in 1984 with area 190 m^2. The school will be again renovated in 2008 (new extension, renovation of insulation, heating system, etc.).

The teachers are complaining about the wind coming through the basement (mostly through the exhaustion holes) from west side.

Figure 13: ES, Itilleq

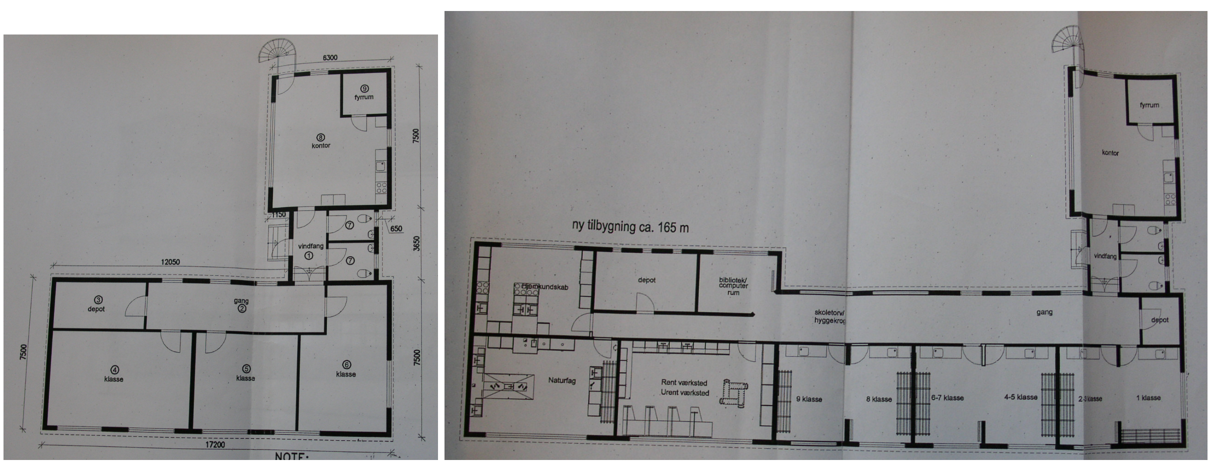

Figure 14: ES, Itilleq, first floor plan and with planned extension

5 Analyzed buildings

5.1 Low Energy Building, Sisimiut

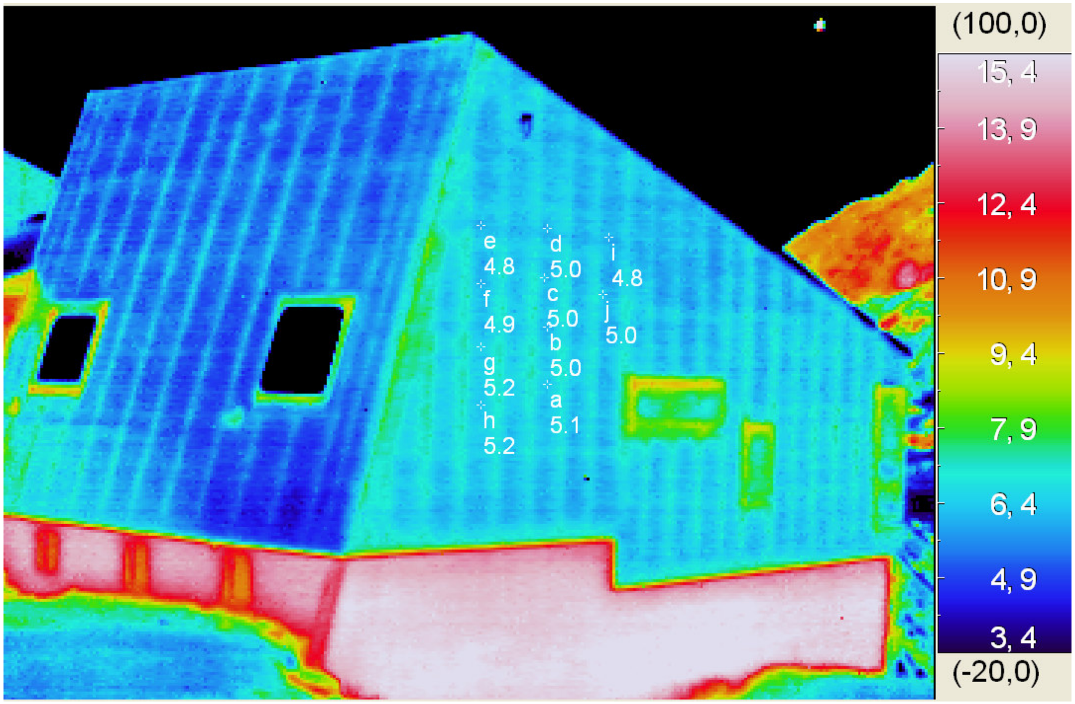

Figure 15: LEH, wall, east view

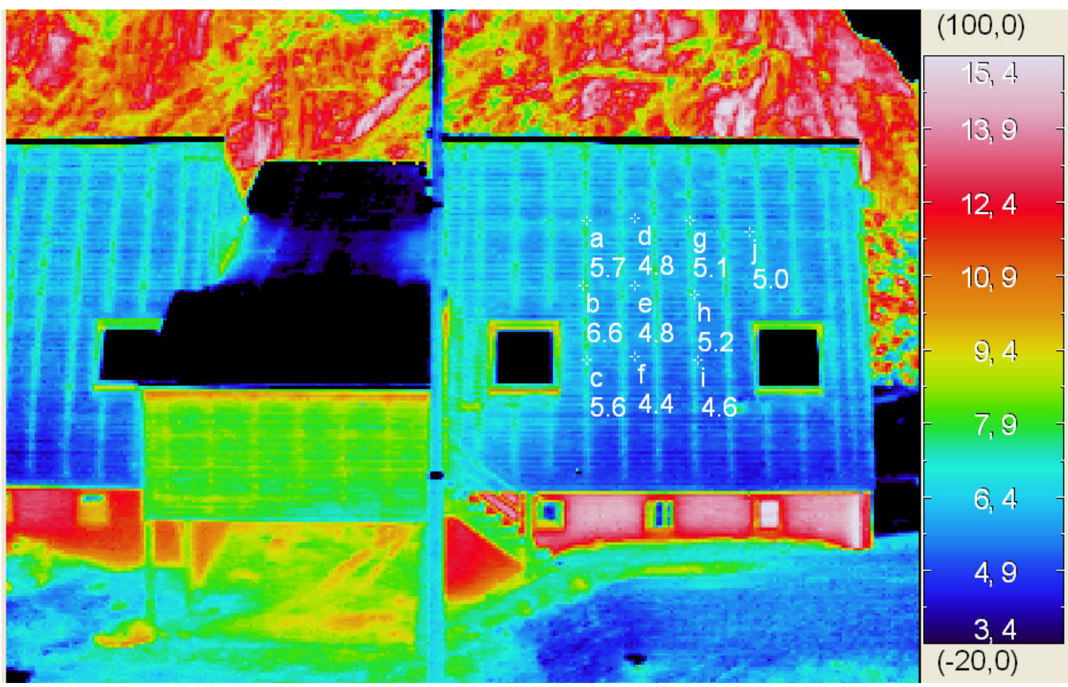

Figure 16: LEH, wall, north-west view

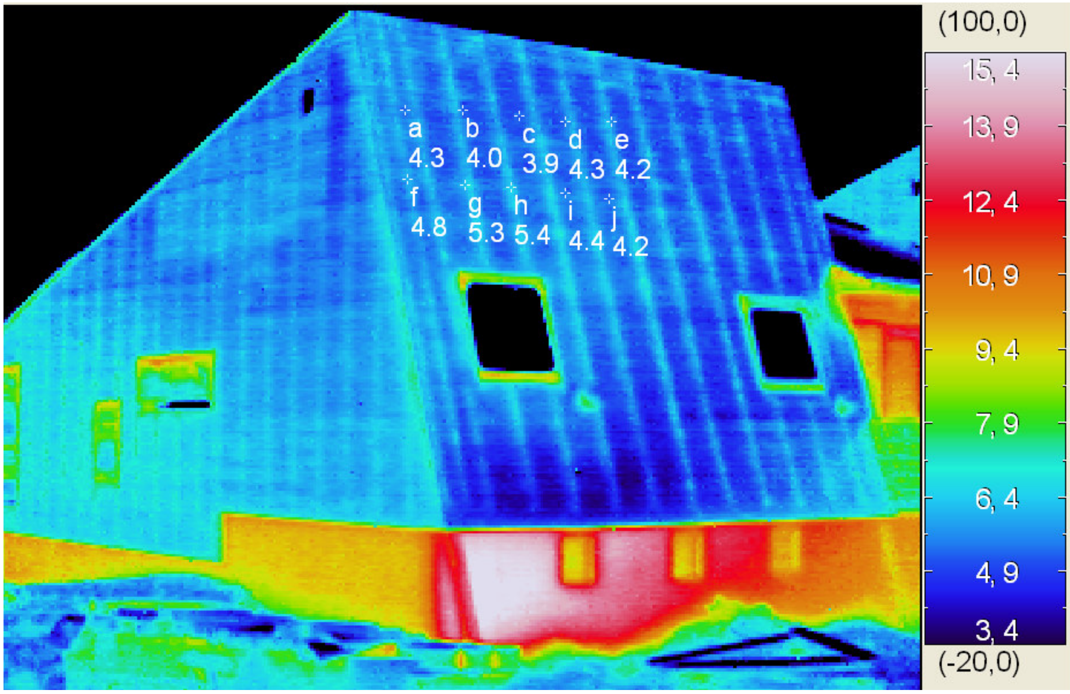

Figure 17: LEH, wall, south-east view

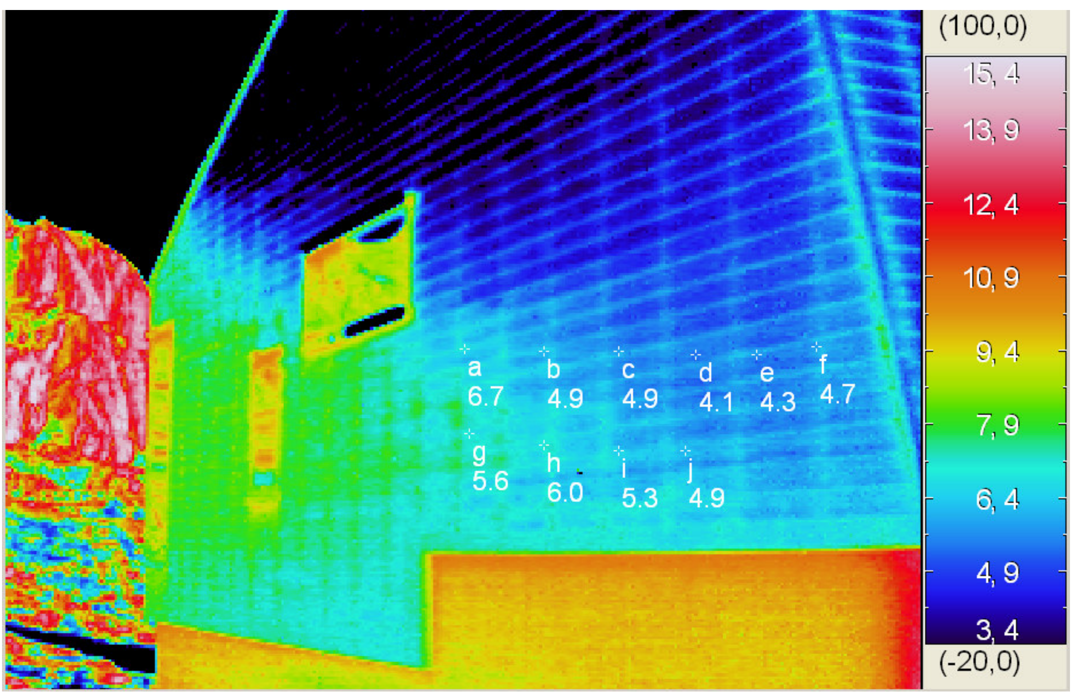

Figure 18: LEH, wall, south view

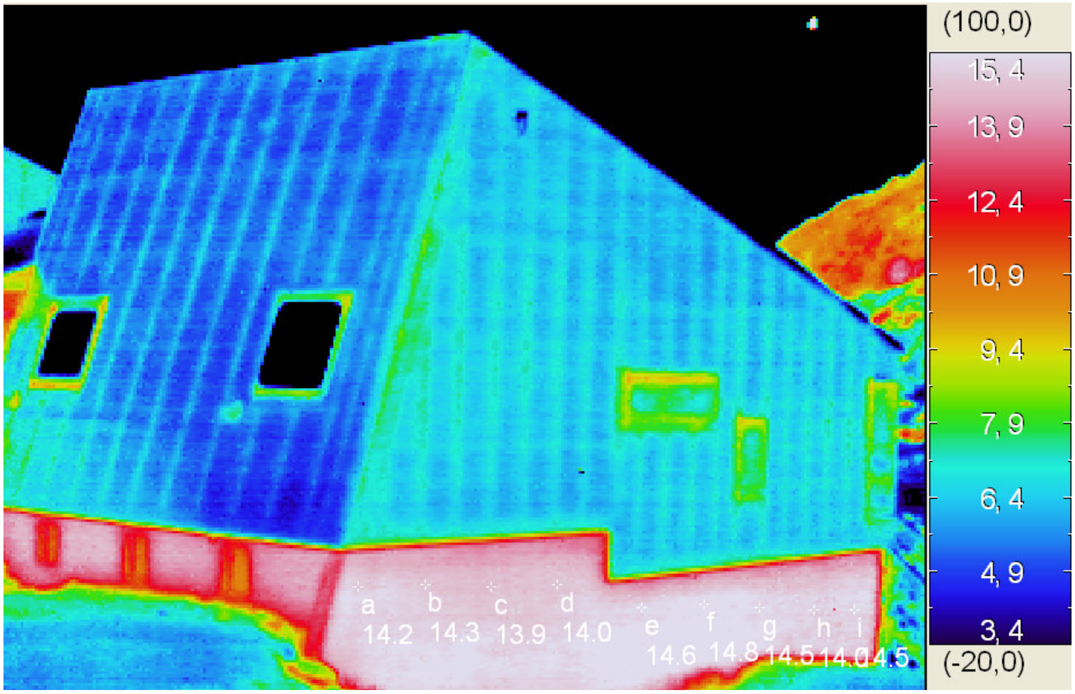

Figure 19: LEH, basement, east view

LEH, Sisimiut		ε	a	b	c	d	e	f	g	h	i	j	Average Temperature [°C]
		[-]	[°C]										
wall	east	0,95 (wood)	5,1	5,0	5,0	5,0	4,8	4,9	5,2	5,2	4.8	5,2	5,04
	north-west		5,7	6,6	5,6	4,8	4,8	4,4	5,1	5,2	4.6	5,0	5,24
	south-east		4,3	4,0	3,9	4,3	4,2	4,8	5,3	5,4	4,4	4,2	4,48
	south		6,7	4,9	4,9	4,1	4,3	4,7	5,6	6,0	5,3	4,9	5,14
basement	east	0,94 (concrete)	14,2	14,3	13,9	14,0	14,6	14,8	14,5	14,0	14,5	14,0	14,28

Table 4: LEH Sisimiut, average temperatures

5.2 Single family house, Sisimiut

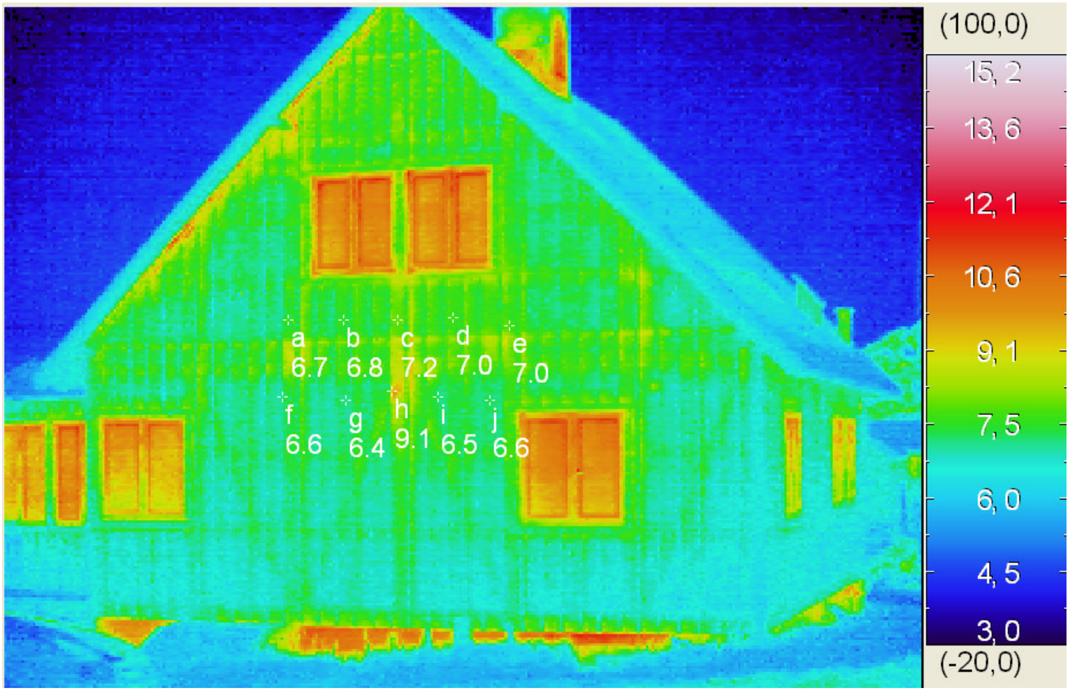

Figure 20: SFH, Sisimiut, wall, east view

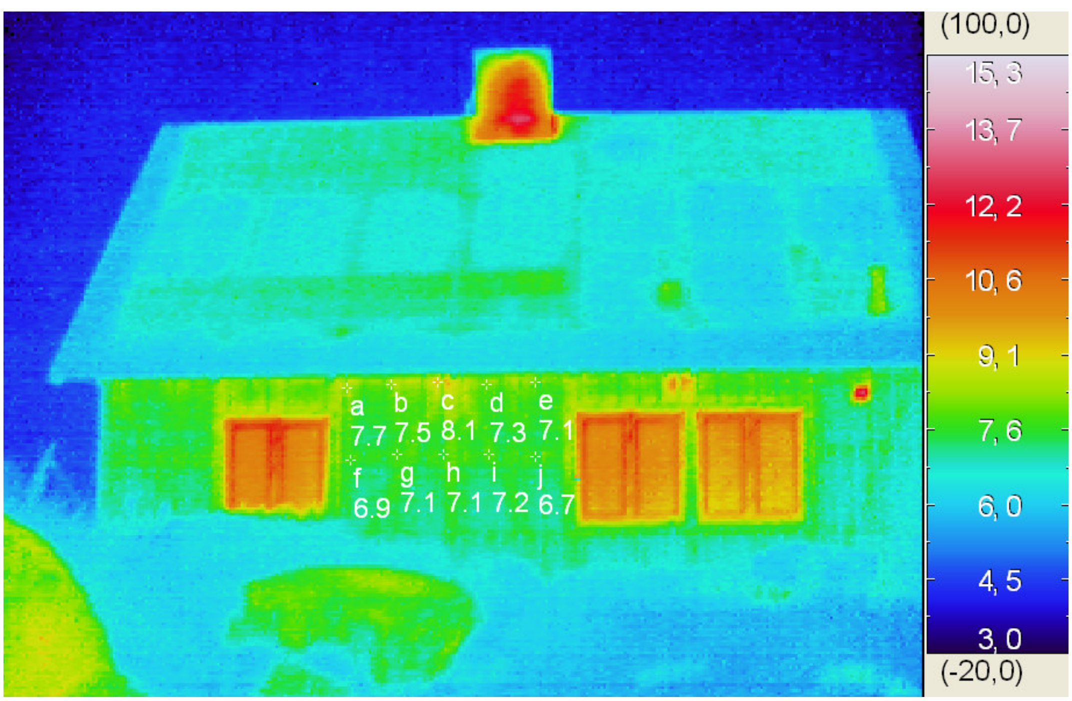

Figure 21: SFH, Sisimiut, wall, north view

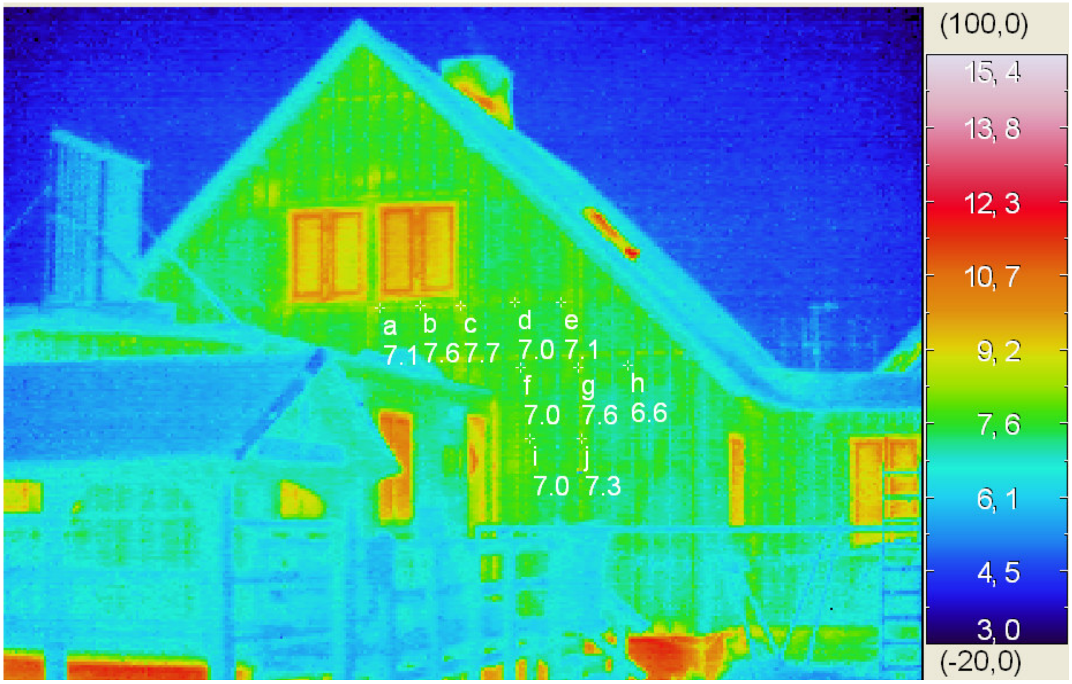

Figure 22: SFH, Sisimiut, wall, west view

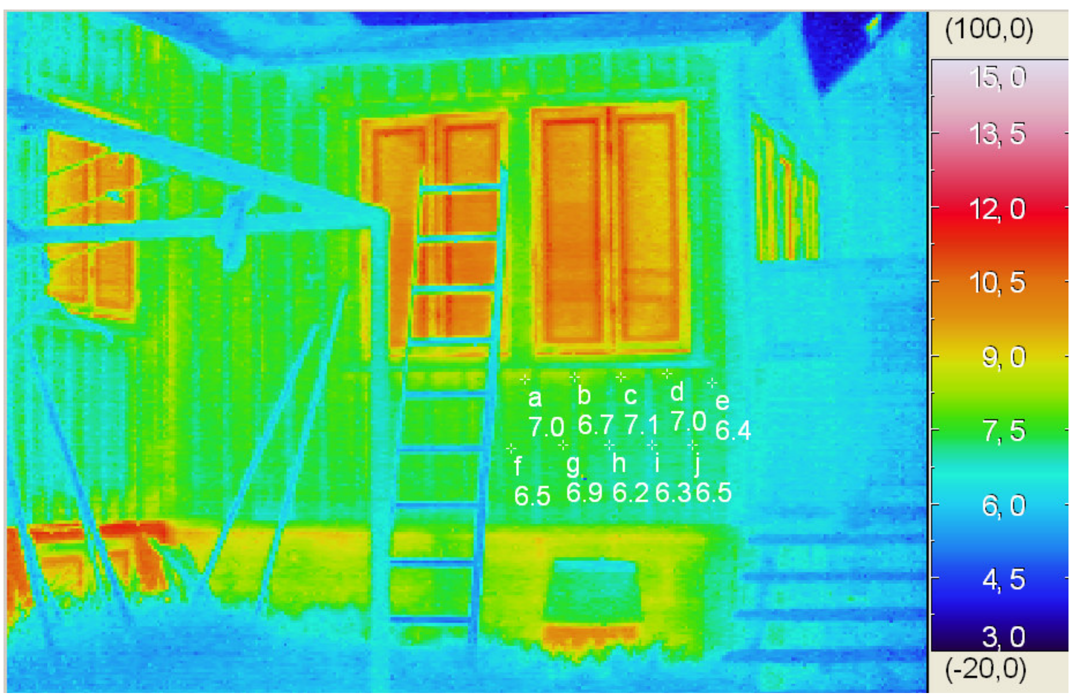

Figure 23: SFH, Sisimiut, winter garden, west view

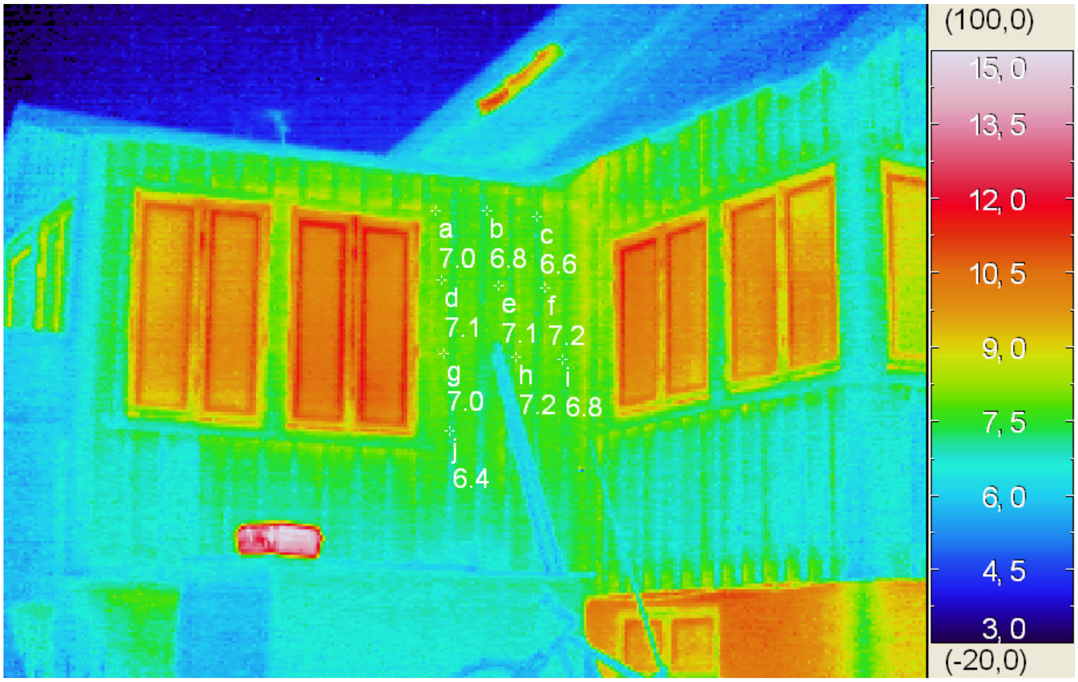

Figure 24: SFH, Sisimiut, winter garden, east view

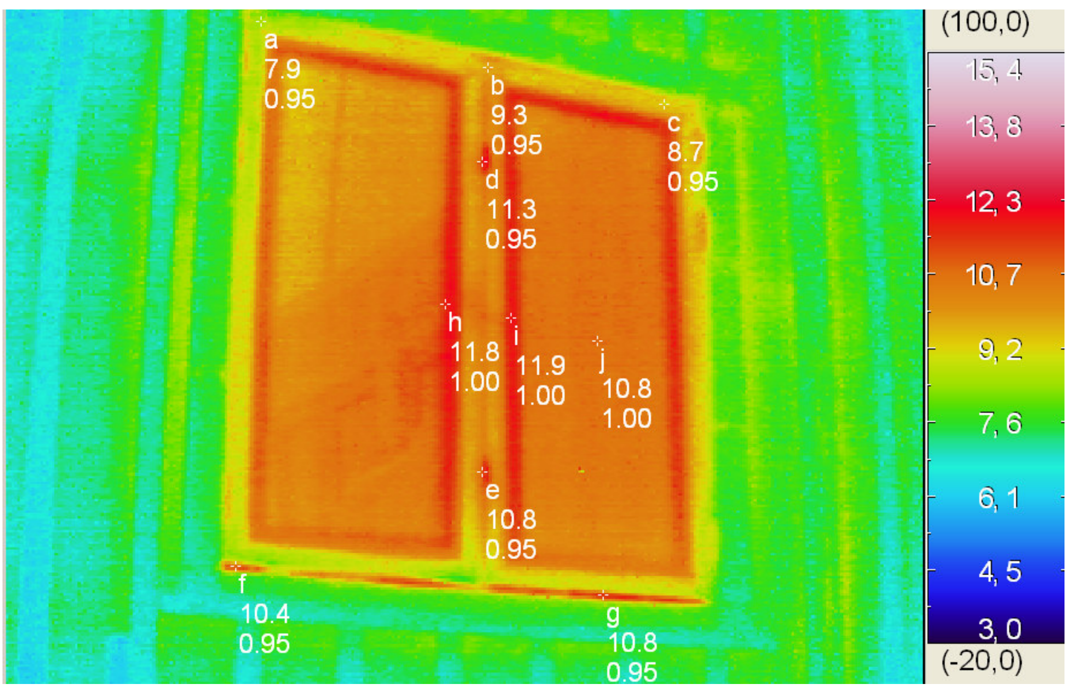

Figure 25: SFH, Sisimiut, window, south facade

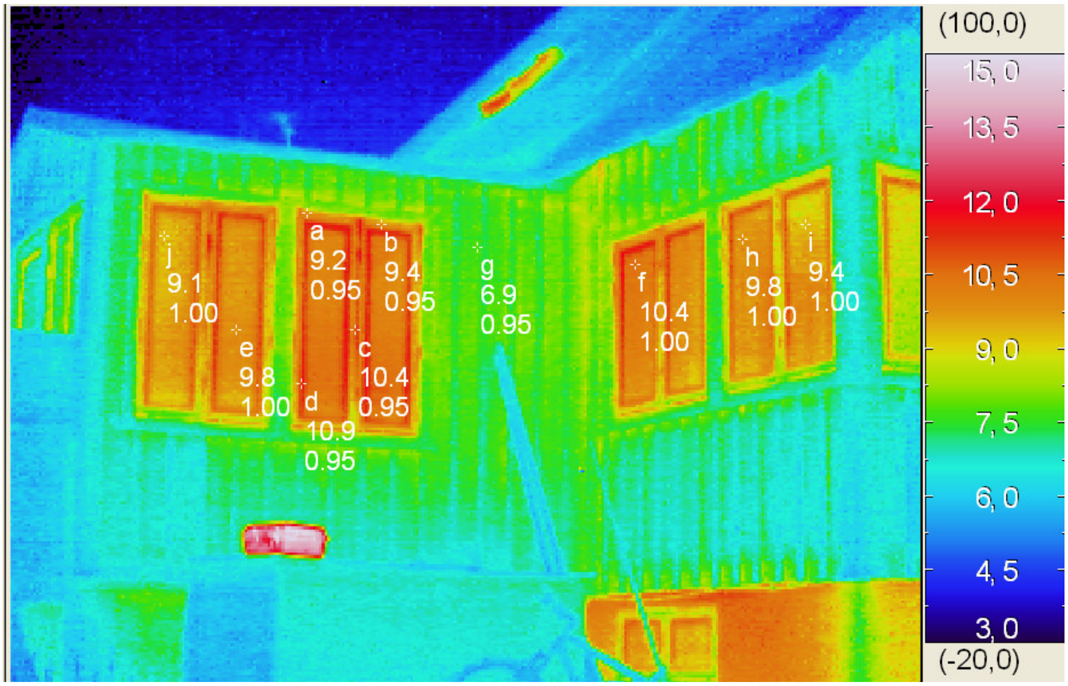

Figure 26: SFH, Sisimiut, window, east facade

SFH, Sisimiut		ε	a	b	c	d	e	f	g	h	i	j	Average Temperature [°C]
		[-]	[°C]										
wall	east	0,95 (wood)	6,7	6,8	7,2	7,0	7,0	6,6	6,4	9,1	6,5	6,6	6,99
	north		7,7	7,5	8,1	7,3	7,1	6,9	7,1	7,1	7,2	6,7	7,27
	west		7,1	7,6	7,7	7,0	7,1	7,0	7,6	7,6	7,0	7,3	7,30
winter garden	west		7,0	6,7	7,1	7,0	6,4	6,5	6,9	6,2	6,3	6,5	6,66
	east		7,0	6,8	6,6	7,1	7,1	7,2	7,0	7,2	6,8	6,4	6,92

Table 5: SFH Sisimiut, average temperatures

5.3 Single family house, Sarfannguaq

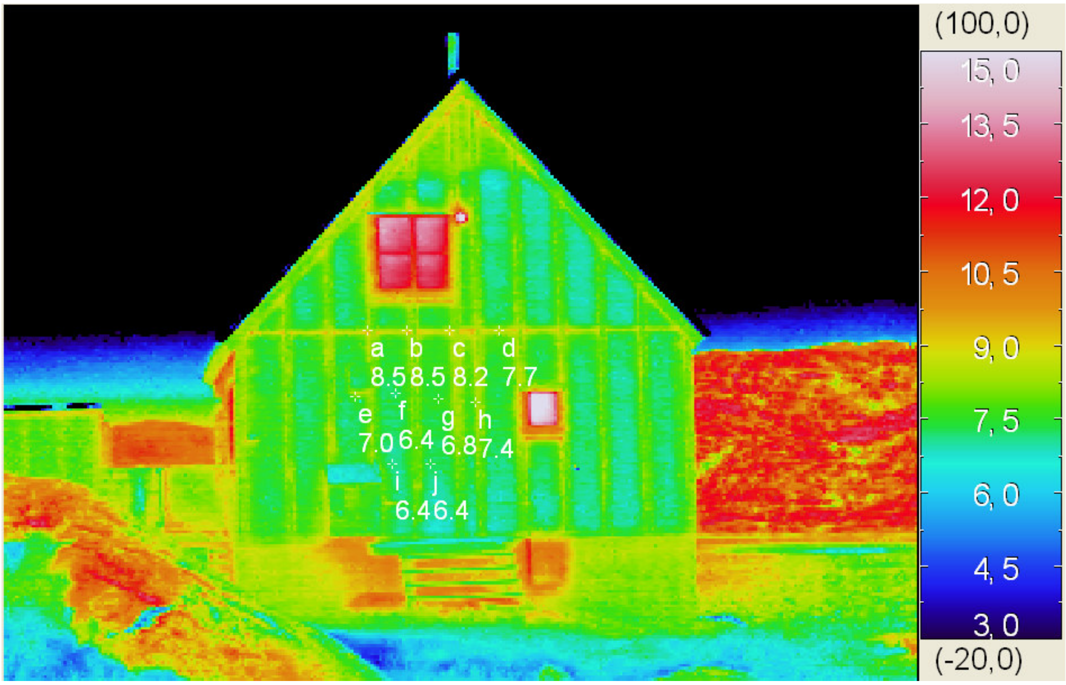

Figure 27: SFH, Sarfannguaq, wall, east view

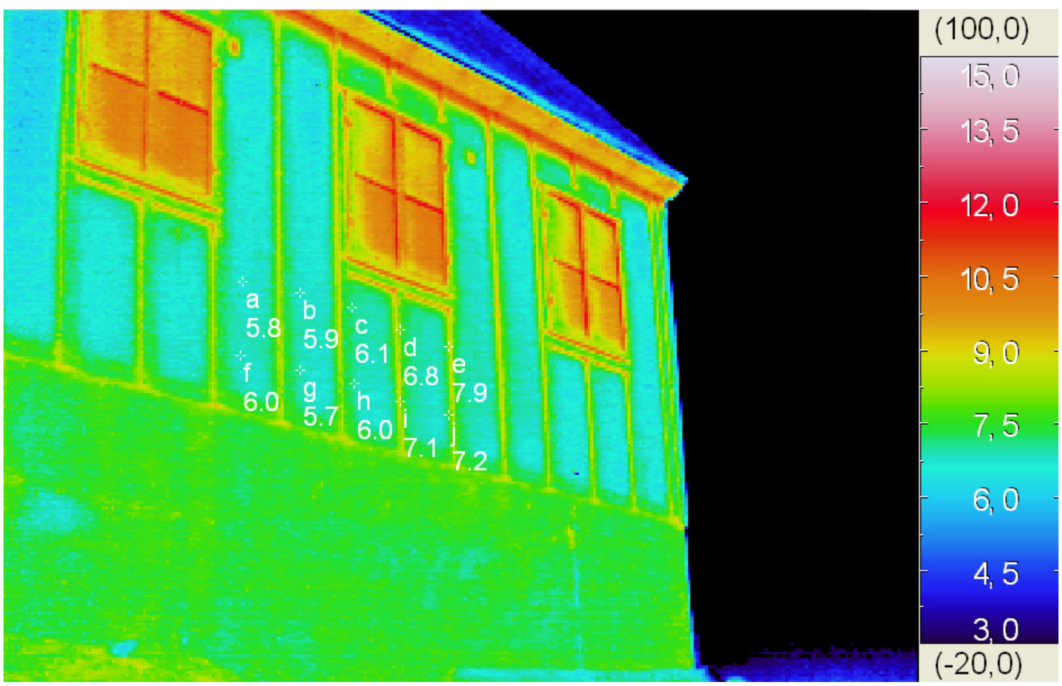

Figure 28: SFH, Sarfannguaq, wall, north view

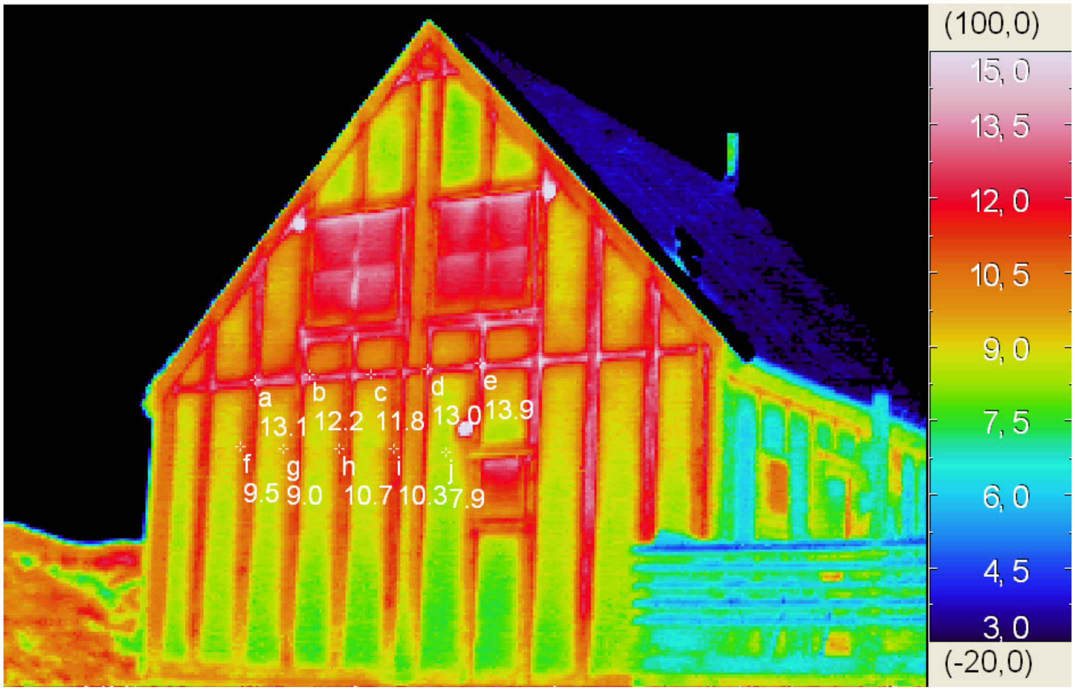

Figure 29: SFH, Sarfannguaq, wall, west view

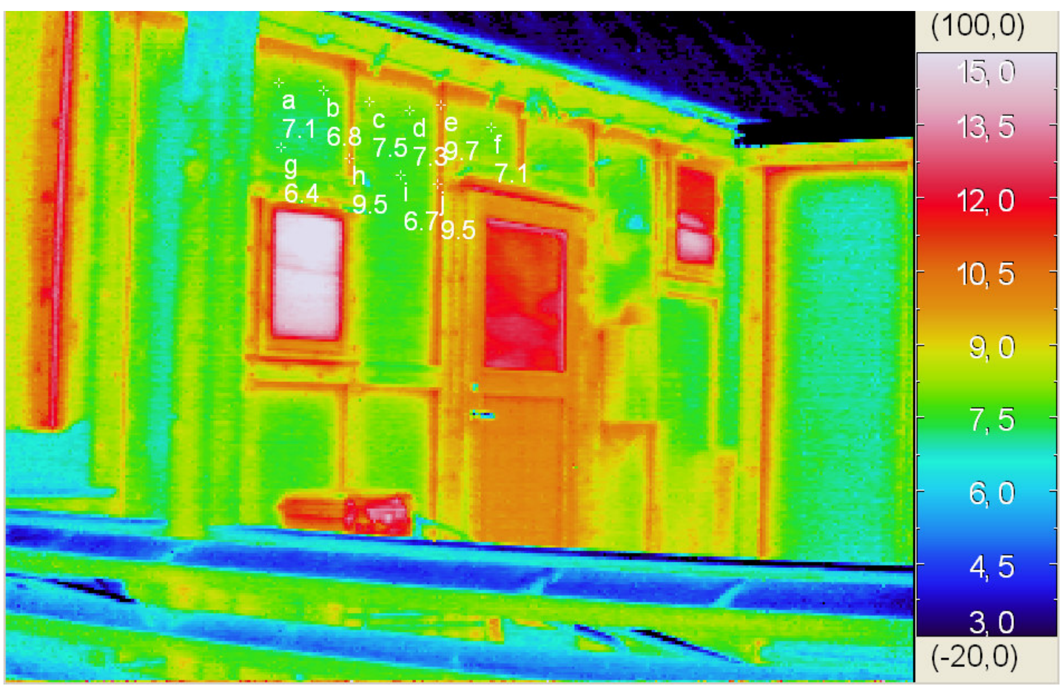

Figure 30: SFH, Sarfannguaq, wall, south view

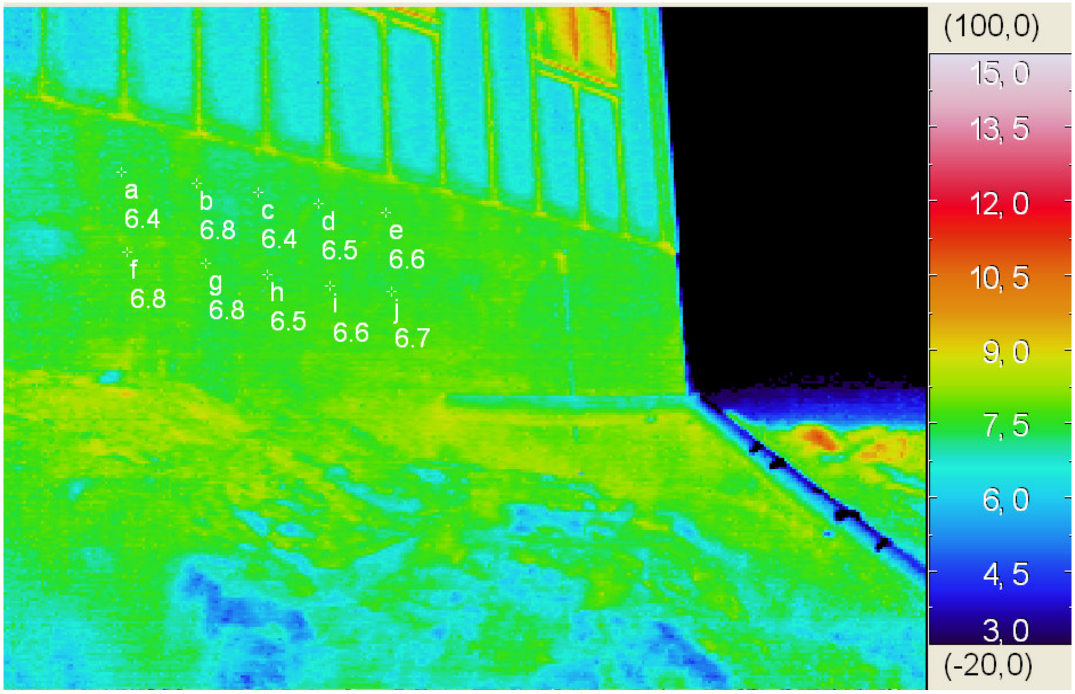

Figure 31: SFH, Sarfannguaq, basement, north view

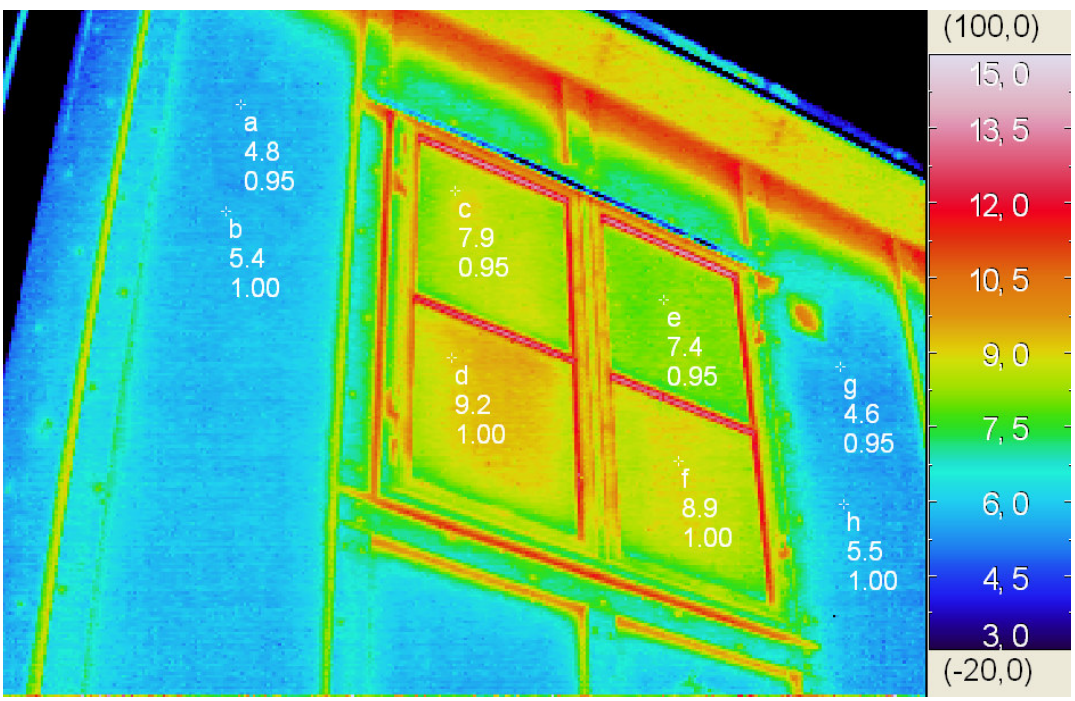

Figure 32: SFH, Sarfannguaq, window, north view

SFH, Sarfannguaq		ε	a	b	c	d	e	f	g	h	i	j	Average Temperature [°C]
		[-]	[°C]										
wall	east	0,95 (wood)	8,5	8,5	8,2	7,7	7,0	6,4	6,8	7,4	6,4	6,4	7,33
	north		5,8	5,9	6,1	6,8	7,9	6,0	5,7	6,0	7,1	7,1	6,44
	west		13,1	12,2	11,8	13,0	13,9	9,5	9,5	10,7	10,3	7,9	11,19
	south		7,1	6,8	7,5	7,3	9,7	7,1	6,4	9,5	6,7	9,5	7,76
basement	north	0,94 (concrete)	6,4	6,8	6,4	6,5	6,6	6,8	6,8	6,5	6,6	6,7	6,61

Table 6: SFH Sarfannguaq, average temperatures

5.4 Elementary school, Itilleq

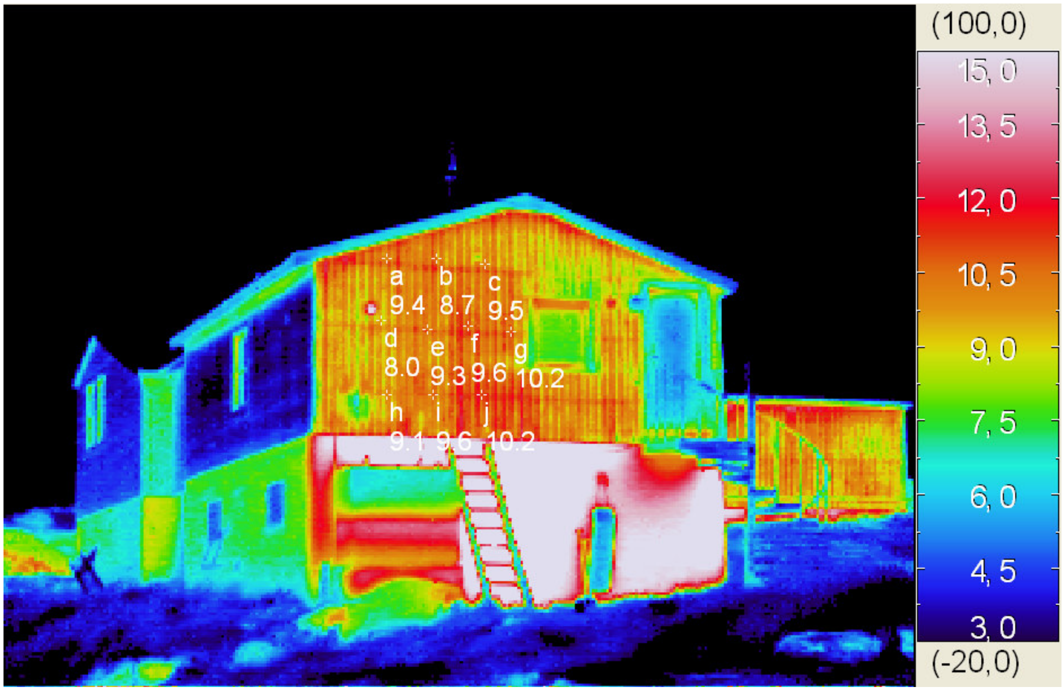

Figure 33: ES, Itilleq, wall, west view

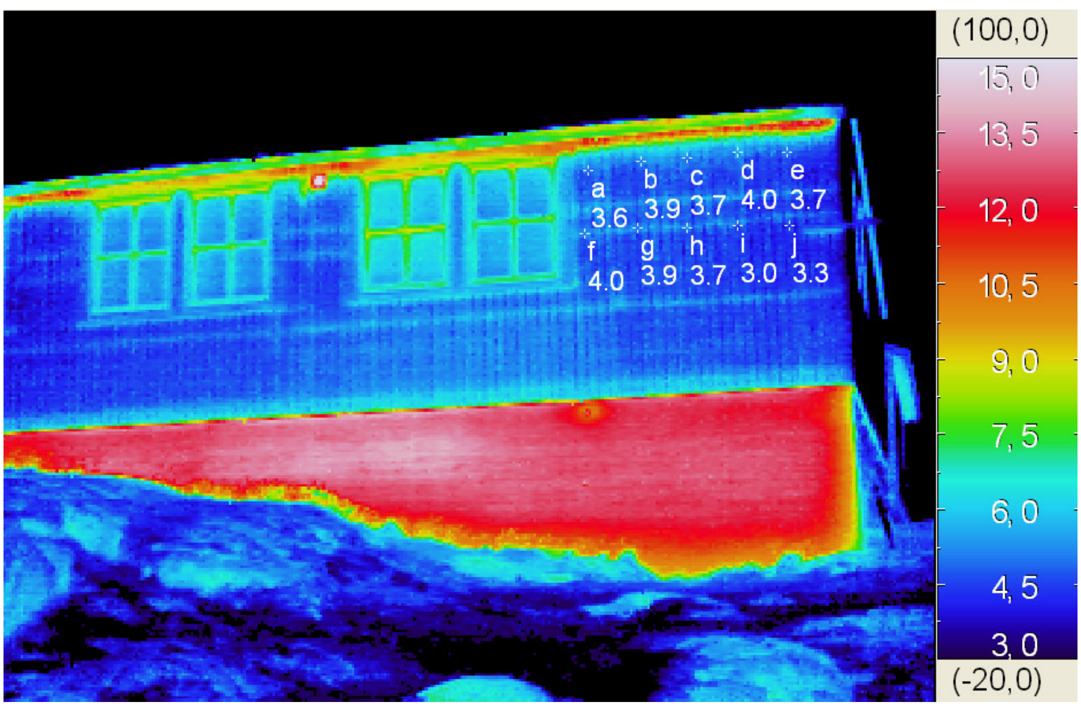

Figure 34: ES, Itilleq, wall, east view

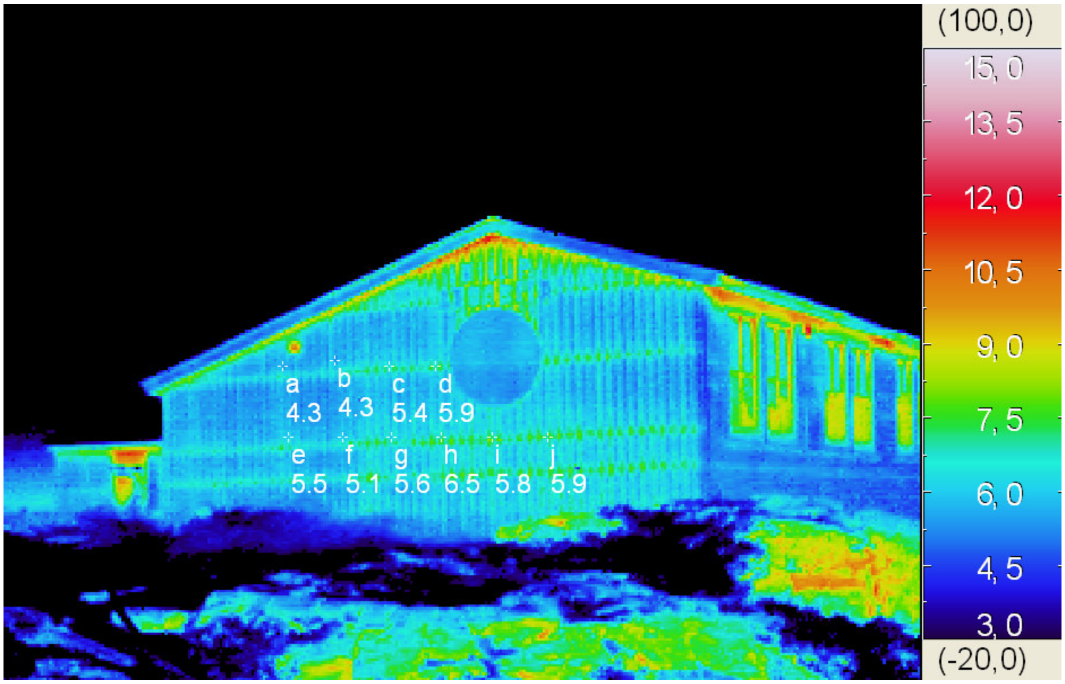

Figure 35: ES, Itilleq, wall, south view

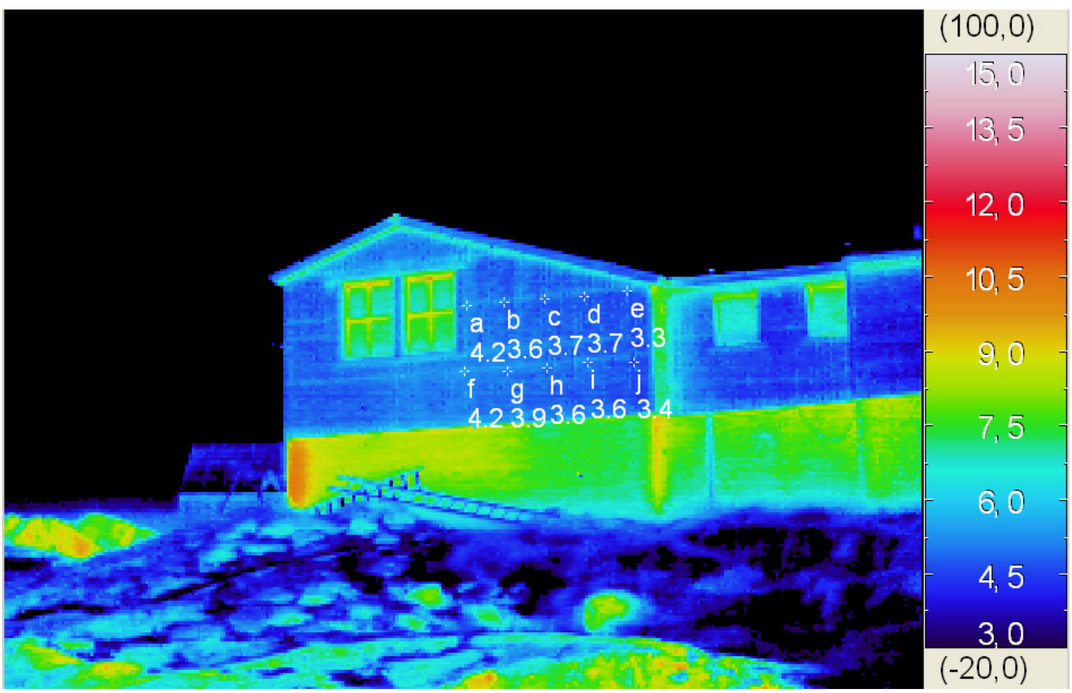

Figure 36: ES, Itilleq, wall, north view

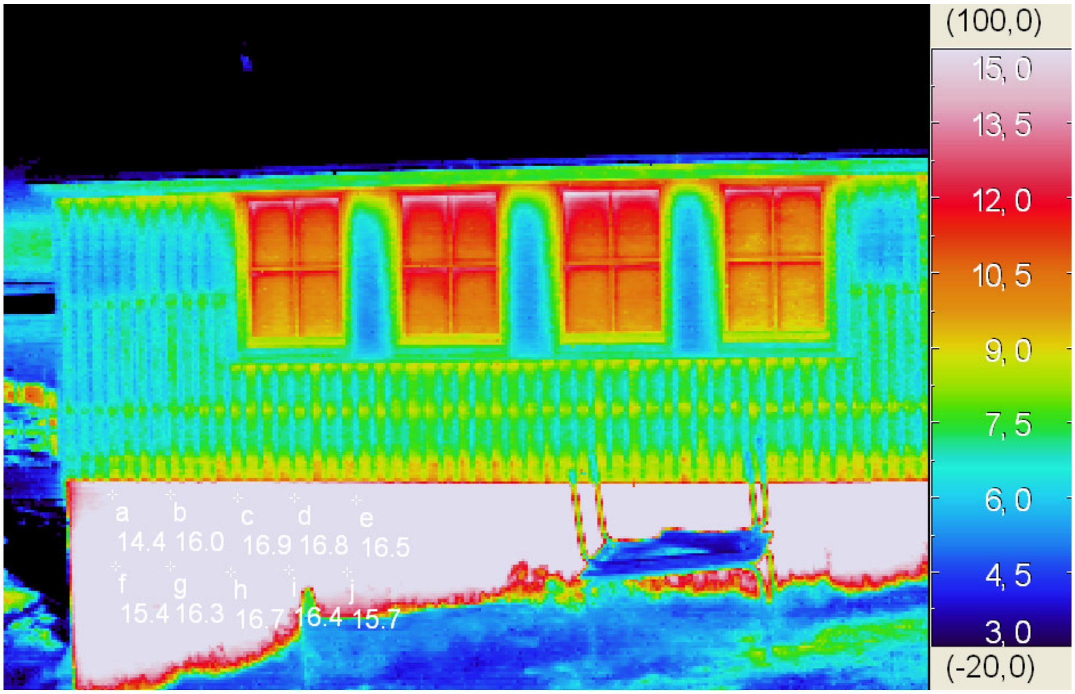

Figure 37: ES, Itilleq, basement, south view

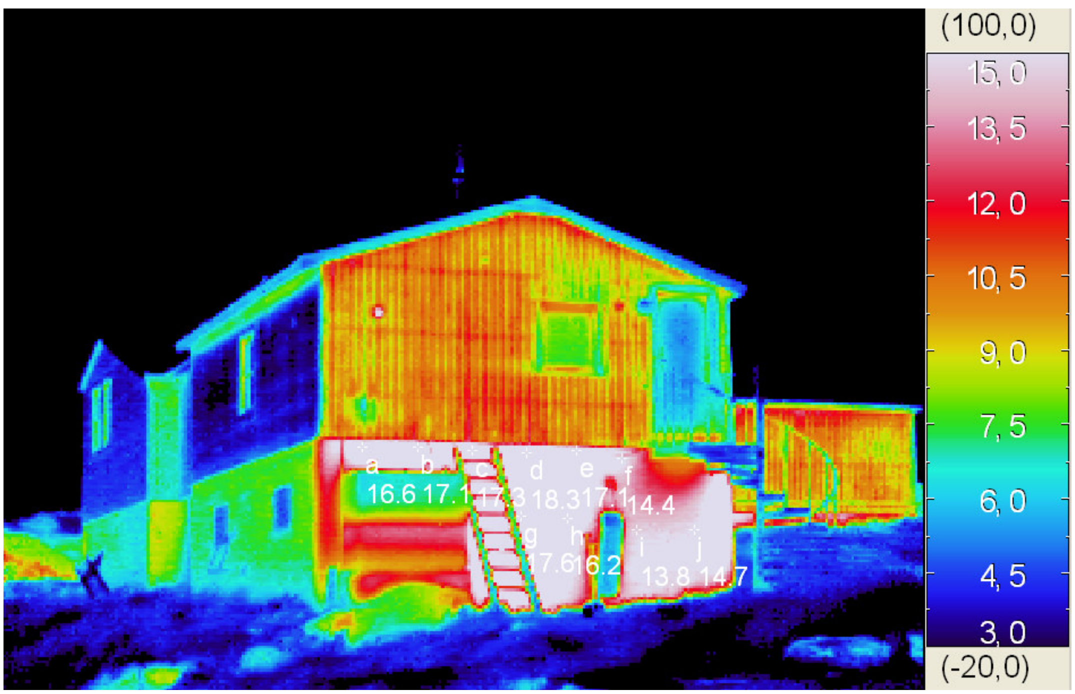

Figure 38: ES, Itilleq, basement, west view

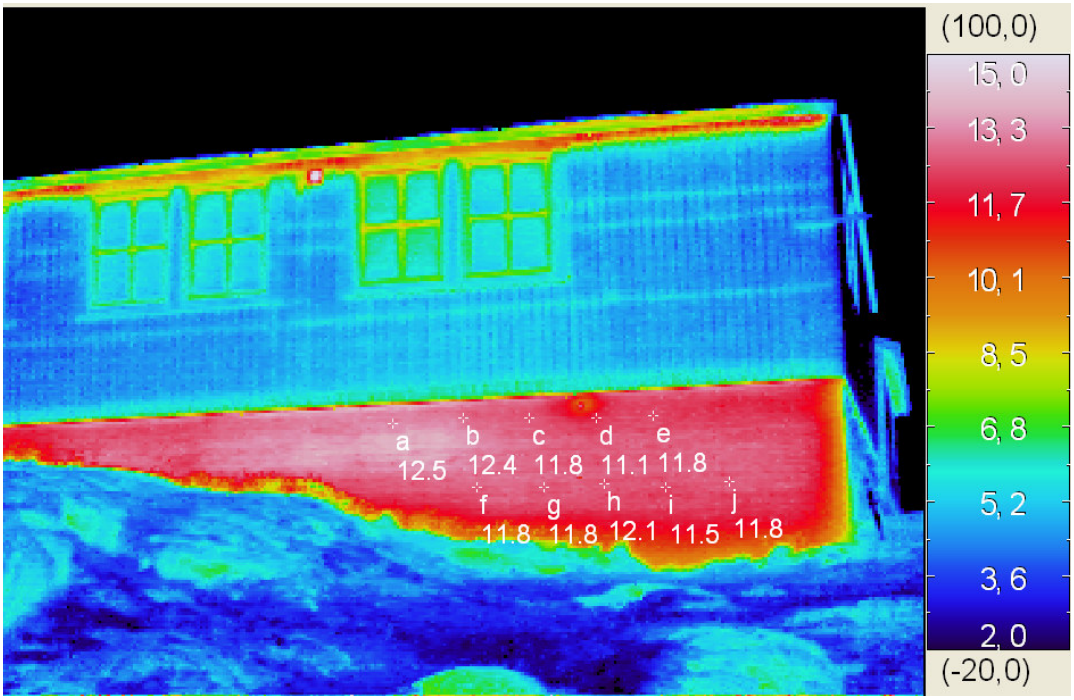

Figure 39: ES, Itilleq, basement, east view

ES, Itilleq		ε	a	b	c	d	e	f	g	h	i	j	Average Temperature [°C]
		[-]	[°C]										
wall	east	0,95 (wood)	3,6	3,9	3,7	4	3,7	4	3,9	3,7	3	3,3	3,68
	north		4,2	3,6	3,7	3,7	3,3	4,2	3,9	3,6	3,6	3,4	3,72
	west		9,4	8,7	9,5	8,0	9,3	9,6	10,2	9,1	9,6	10,2	9,36
	south		4,3	4,3	5,4	5,9	5,5	5,1	5,6	6,5	5,8	5,9	5,43
basement	south	0,94 (concrete)	14,4	16,0	16,9	16,8	16,5	15,4	16,3	16,7	16,4	15,7	16,11
	west		16,6	17,1	17,3	18,3	17,1	14,4	17,6	16,2	13,8	14,7	16,31
	east		12,5	12,4	11,8	11,1	11,8	11,8	11,8	12,1	11,5	11,8	11,86

Table 7: ES Itilleq, average temperatures

6 Analyzing of results

			min value [°C]	max value [°C]	average [°C]
LEH, Sisimiut	wall	east	4,8	5,2	5,01
		north-west	4,4	5,7	5,11
		south-east	4,0	5,4	4,63
		south	4,1	5,6	4,95
	basement	east	4,1	14,8	11,06
SFH, Sisimiut	wall	east	6,4	9,1	13,42
		north	6,7	8,1	7,36
		west	7,0	7,7	7,33
	winter garden	west	6,2	7,1	6,65
		east	6,4	7,2	6,84
SFH, Sarfannguaq	wall	east	6,4	8,5	7,41
		north	5,7	7,9	6,68
		west	7,9	13,9	11,00
		south	6,4	9,7	7,95
	basement	north	6,4	6,8	6,60
ES, Itilleq	wall	east	3,0	4,0	3,56
		north	3,3	4,2	3,74
		west	8,0	10,2	9,19
		south	4,3	6,5	5,41
	basement	south	14,4	16,9	15,80
		west	13,8	18,3	16,14
		east	11,1	12,5	11,82

Table 8: Calculated minimum, maximum and average temperature

	Min [°C]	Max [°C]	ΔT [°C]
LEH, Sisimiut	4,0	5,7	1,7
SFH, Sisimiut	6,2	9,1	2,9
SFH, Sarfannguaq	5,7	13,9	8,2
ES, Itilleq	3,0	10,2	7,2

Table 9: Temperature difference for walls

		Min [°C]	Max [°C]	ΔT [°C]
LEH, Sisimiut	basement wall	-	-	-
SFH, Sisimiut	winter garden	6,2	7,2	1,0
SFH, Sarfannguaq	basement	6,4	6,8	0,4
ES, Itilleq	basement	11,1	18,3	7,2

Table 10: Temperature difference for winter garden and basements

7 Discussion of results

The measuring was taken by photo camera to establish the normal image of house and followed by themo vision image from each spot taken by thermo camera ARTRAY ARTCNV-NECS1. This was repeated from every possible side of the house to obtain the best possible position and image. Obtained images were analyzed in simple software Viewer Program (TH78-719) where the emissivity for a point was set up for each material (emissivity value was taken from Table 2, reference value).

As the software uses only a single point with determined emissivity (complex software measure the emissivity of the whole picture, or minimum a square) for each image was determined a matrix consisting of 10 points (a-j) on the wall surface. From this matrix the minimum, maximum and average temperature were calculated (Table 8).

Low Energy House, Sisimiut, where the U-value of walls was calculated 0.15 W/m^{2}K (300 mm insulation), shows results for average temperature from 4.95 to 5.01 °C with temperature difference ΔT = 1.7 °C. Such a small temperature difference indicates very homogeneous wall where the temperature field is very uniform. Which means that the heat coming (or escaping) from inside to the exterior is minimal and the wall composition (with suitable insulation thickness) is very well designed and realized. The basement temperature value was not evaluated as there is no basement actually and the value only shows temperature of single concrete wall.

Single family house, Sisimiut, with insulation thickness 175 mm in the walls of the house, is the average temperature from 6.2 to 9.1 °C with temperature difference ΔT = 2.9 °C, which is almost a double number in comparison to Low Energy House. This would lead to results that the house is not so well insulated and it would be wise to add more insulation. But the main problem (Figure 23, Figure 24) is the winter garden and its connection to main part of the building from main part of the house. The wall of winter garden indicates quite good field of temperature (ΔT = 1.0 °C), but the measurements were only taken from west and east side of the winter garden, the most crucial side from open area from sea was not possible to measure. Another problem will be the current conditions of windows (Figure 25, Figure 26) where emissivity for wooden frame was determined and shows the temperature difference from 7.9 to 11.3 °C (ΔT = 3.4 °C) which is alarming number. It can be said that those are the most dangerous places in the whole house together with not very well conditions of connection parts of winter garden and main part of the house.

The recommendation for single family house, Sisimiut, would be to add extra insulation to the whole house and especially be aware of connection point with winter garden and also the connection point where the main beam go through the building (Figure 20, spot in the middle of the building´s wall). Those connection points should be really taken care of and the execution of workmen should be really watched and supervised carefully. But the main would be changing the windows for at least double (triple) glazing with U-value around 1.5 W/m^{2}K.

Single family house, Sarfannguaq, has 150 mm of Rockwool insulation and the temperature difference is from 5.7 to 13.9 °C (ΔT = 3.4 °C)*. This large value can be explained by west side of the building which is open to sea wind and there exist the biggest values of temperature differences, and for years the wall has been weakened from this wind (Figure 29). The temperature difference for basement which varies from 6.4 to 6.8 °C (ΔT = 0.4 °C) is quite sufficient.

*Value for west wall is 7.9 to 13.9 °C (ΔT = 6.0 °C). Value for the other three walls is from 5.7 to 9.7 (ΔT = 4.0 °C).

Recommendation for single family house, Sarfannguaq, as the normally weakest point of the house - windows have been changed recently (before measuring took a part), the only thing to recommend would be to insulate the whole house walls (also basement walls), and especially focus on west side of the house where even more insulation will be needed. Also the exhaust vents should be taken care of and insulated (Figure 27, on the front side of the house on the right from the window) to prevent cold air coming in.

Elementary school, Itilleq, has 130 mm of wall insulation and the temperature field differs from 3.0 to 10.2 °C (ΔT = 7.2 °C) **. Where this large number is due sun setting down on west side and as the measuring was taken around midnight and the sun set down around 10 p.m., this cannot be taken as reliable value (the measurement should have been taken during the morning hours). For basement values where the temperature difference is from 11.1 to 18.3 °C (ΔT = 7.2 °C) and where the biggest heat escapes occurs due the ventilation exhausts, for the concrete evaluation more information will be need it.

**Value for west wall is 8.2 to 10.2 °C (ΔT = 2.0 °C). Value for the other three walls is from 3.0 to 6.5 (ΔT = 3.5 °C).

Recommendation for elementary school, Itilleq, due to complaints of coming cold air through the basement, this should be taken care of and insulated. The school is being renovated and extended (towards south) therefore the current walls of the building could be extra insulated as well. The windows are double glazing and seem to be in good conditions, maybe towards west could be changed as this is the most effected part of the house.

Mistakes during the measurement

- Time and date: should be taken in heating season (in Greenland during the whole year); the measuring should have been done in morning hours for reason to really let cool down the building as the sun reflects on surface and also heats up the surface of buildings during the entire day.
- Emissivity of wall´s materials could be measured directly in situ using techniques described above and getting more precise emissivity value

Software limitations

There were made some simplification due software limitation as for instance the „reflected temperature“, temperature and air humidity were neglected. More information materials, better software and more practising would be needed for more exacts results. Also the roofs of the building were not measured but they should be also checked and insulated, as the sloping roof is the most effortful and stressed part of the house.

8 Conclusion

As Greenland is quite an unusual place for taking thermo graphic measurements around North Polar circle where the day lasts half of the year (not completed dark during the nights, low darkness for approximately 4-6 hours) and the other half of the year is a polar night, this measurement and results should be taken as a first experimental measurement.

The task of the measurement and report was to compare different buildings using thermo vision camera, mainly the task was to make a survey of Greenland´s current housing situation and state the conditions of existing buildings and conditions of walls. Furthermore the task was to analyze the measured thermo graphy images and compare them together. Thermovision from exterior was used to determine and evaluated the homogenity of temperature field in the walls and shows the weakest points of the building (thermal bridges) and heat flows through the walls (values on the exterior surfaces of walls). The higher temperature indicates that something is wrong and should be checked more closely.

Basically the report shows the comparison between the newest Low Energy House and current building (family houses and school). The best values and performance are from Low Energy House, Sisimiut. The next will be elementary school in Itilleq and single family house in Sarfannguaq. The worst evaluated will be the family house in Sisimiut. Mainly it can be said that the results also follows the construction year of buildings (the newest the best).

The task of measuring thermovision in Greenland was a very interesting project and it could be a possible Bachelor or Master project for a student to documented and measure existing buildings and its current situation in Sisimiut and/or Greenland. Later those results could be used to compare the housing situation in Greenland with Danish housing situation (or even with the overall world´s housing situation). Also this results can be taken further with analyzing thermal bridges, U-values (calculated and from manufacturer), moulds, etc.

9 Contact list

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10 Literature

[1] Greenland, www: Greenland, The Sins of Past, 2008

[2] Atelier Dek, Czech Republic, www: Termovize

[3] iMaterialy, Czech Republic, www: Infrared Termography as Methods for Modern Diagnostics

[4, 5] Rostislav Szeruda, www: Pyrometry - Basics
Mikron Infrared, USA, www: Operator´s manual
Raytek, www: Raytek - Emissivity of Most Common Materials
Javelin, www: Emissivity of materials

[6] Wikipedia, www: Solar Energy
Brichnac, Czech Republic, www: Meterology and Klimatology

[7] Jens Ch. Madsen, "Grønlandske boliger – selvbyggeri og typehuse", Forlaget Atuagkat, 2000.

[8] Jiri Svoboda,"Termodiagnostika – ucebni texty", TMV SS, 2007. (English title: "Termodiagnostics - teaching texts")

EN 13187: Thermal performace of buildings – Qualitative detekction of thermal irregularities in bulding envelopes – Infrared method, 1998